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ABSTRACT

This study was conducted in order to compare the effects of immediate practice and delayed practice on retention of learned rules. Seventh-grade students (N=103) were instructed on three rules of operation with exponents by programmed text. These subjects were randomly assigned to five treatment groups: (1) no practice, (2) one practice trial on the first day, (3) five practice trials on the first day, (4) one practice trial on the fifth day, and (5) five practice trials on the fifth day. On the twenty-first day of the study, all subjects were given a retention test. Findings indicated that delayed practice was significantly more effective than immediate practice as a means of providing for retention. Five delayed trials were not more effective than one delayed trial, nor was immediate practice more effective than no practice. (SD)

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EFFECTS OF AMOUNT OF IMMEDIATE AND OF DELAYED PRACTICE ON RETENTION OF MATHEMATICAL RULES

BEST COPY AVAILABLE

Stephen Horwitz

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SE020 481

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INTRODUCTION

Much of what is learned in the classroom is too soon forgotten. Pressey, Robinson, and Horrocks (1959) found evidence that as much as two-thirds of the concepts learned in high school and college courses are forgotten within two years. Numerous other studies conducted in the area of forgetting have yielded results which indicate students forget a large proportion of what is learned in the classroom. Among these studies are those of Tyler (1933), Layton (1932), Lahey (1941), and Sterrett and Davis (1954).

Not all types of learned material are forgotten to the same degree, however, Research indicates that learning which deals with the application of rules and principles seems to be retained somewhat better than that which deals with factual material. Tyler (1930), for example, in a study of retention of information from a high school science class found that, after eight months, "...the greatest loss during the year was in information about science, whereas there was little or no loss in the ability to explain everyday phenomena and the ability to generalize from given facts." Other results which point to higher retention of rules and their applications, when compared to factual information, can be found in the studies of Briggs and Reed (1943), English, Welborn, and Killian (1934), Sterrett and Davis (1954), Freud and Cheronis (1940).

Ausubel (1968) also cites evidence indicating that rules and their applications are better retained than factual information. In addition, he cites evidence that the retention of factual material is

improved if the material is presented in a meaningful manner. Both of these types of evidence have led Ausubel to suggest that the large retention losses found by many studies are not necessarily inevitable and that some forgetting is reflective of such factors as rote learning of poorly organized and programmed subject matter, correctable ambiguity and confusion in the presentation of ideas and inadequate pacing and review of material.

STATEMENT OF THE PROBLEM

Learning of rules and principles was identified as a particular type of learning by Gagné (1972) and classified within his domains of learning as an intellectual skill. It is the retention of these intellectual skills and of rule learning in particular which provides the focus for the present study.

The learning of rules is itself of vast educational importance, if for no other reason than that rules make up the bulk of what is learned in the schools (Gagné, 1970). It is also of importance that rules govern a larger class of behaviors and their mastery and continued retention enables one to respond properly to various stimulus situations.

Ausubel (1968) suggests that it is possible to improve retention by eliminating shortcomings in the organization, presentation, and review of learning material. According to this conception, practice, as a form of review, might prove a valuable tool in improving the retention of rule learning, but all too frequently, practice assignments are based on past experience, the exercises provided in textbooks, considerations pertaining to the amount of material to be covered, or even whim. It is

therefore, the purpose of this study to investigate the influence of the placement and number of practice trials on the retention of rules. When "practice" is used in connection with rule learning, the kind of activity referred to is the application of the rule to examples (instances of the rule), and a "trial" of practice is an occasion on which a previously unencountered instance of the rule is responded to by the learner.

REVIEW OF THE LITERATURE

Number of Practice Trials

Despite its immense practical significance for classroom learning, little experimental research has been conducted on the relationship between number of practice trials and delayed retention of meaningfully learned material.

Differences of opinion do exist, however, as to whether this relationship is such that a larger number of practice trials aid retention, or whether, beyond a certain point in the learning process, additional amounts of practice have no appreciable effect. Anderson and Faust (1973:442-56) and Ausubel (1968:273-89), for example, support the position that additional practice has a positive effect on retention. Gagné, on the other hand, suggests that, at least in the domain of intellectual skills,

> "...it is not at all clear that the variable of amount of initial learning is of such importance. If a concept or rule has been completely learned, (in the sense that it can be applied to a novel example) it is entirely possible that additional practice may have no appreciable effect on its retention." (1970:319)

In the area of information or verbal learning, several studies have indicated the tendency for additional practice at the time of

original learning to increase delayed retention. (It may be noted, as a clarifying point, that "practice" of verbal items or passages refers to repetition of the same items.) Gilbert (1957) found that delayed retention on tests 15 minutes, one day, and two days after original learning, was directly related to degree of overlearning. Similarly, Slamecka (1959) found that delayed recall was directly related to number of repetitions.

Other studies of verbal learning, while noting the positive effect of increased practice on retention, have also indicated a tendency for the learning curves to be negatively accelerated and to eventually level off. McTavish (1949), for example, showed that the first repetition of a film on general science substantially increased retention, but that the second and third repetitions added little or nothing to the effect of the first. Likewise, Rothkopf (1968) found that correct responses increased as a function of repeated exposure to the passage but that the learning curve was negatively accelerated and leveled off after two inspections.

Craig, Sternthal, and Olshan (1972) examined the relationship between overlearning and the retention of print advertisements. Results obtained from the retention scores in this research were not conclusive, but overall indications were that some repetition beyond that required to learn stimulus materials results in better retention than does repetition just sufficient to insure learning.

In contrast to those cited above, other studies of information learning have failed to show any differences in delayed retention as a result of additional practice. One well-known study of this group is

that of Reynolds and Glaser (1964). Using an instructional program to teach ten topics in biology, Reynolds and Glaser inserted frames containing half as many repetitions of technical terms in one case and one and one-half times as many repetitions in another as those in the original groups. After three weeks, the retention of these items was measured. The investigators were unable to find any differences in retention as related to the amount of repetition. Similarly, Chierpilowski (1971), Dopra (1973), and Boyd (1973), found no evidence that delayed retention was increased as a result of an increased number of practice trials.

Much of the research on practice and retention of intellectual skills has also failed to indicate any differences in retention attributable to number of practice trials. Shuster and Pigge (1964), while not directly assessing the effects of different numbers of practice trials did investigate amount of class time spent on practice versus that spent on developmental activities. The term developmental activities was used to refer to those activities of the teacher and class intended to increase understanding of the number system, the fundamental processes, and the general usefulness of number and quantity in everyday experience. Their findings suggest that long and extensive sessions with practice on exercises is not desirable. Studies comparing class time spent on practice with that spent on developmental activities were also conducted by Shipp and Deer (1960) and Zohn (1966). Findings tend to agree that more than 50% of class time should be spent on developmental activities.

In two experiments conducted by Bassler, Curry, Hall, and Healy (1971), the variable of number of practice examples was investigated. Seventh grade students received instruction on a hierarchically designed

mathematical task and practiced each skill either 1, 3, or 5 times. Four weeks after original learning a retention test was administered which required the students to be able to apply the rules previously learned. Results of this first experiment indicated very low performance on both achievement and retention measures and did not find any differences in achievement or retention scores among groups. The second experiment was a replication of the first, using subjects of above average I.Q. Although overall performance in this experiment was higher, the retention test again indicated no differences in scores among groups.

Hannum (1973) studied the effects of cues, and different conditions of learning, one of which was overlearning, upon the retention of three rules in electricity. The overlearning was determined by the number of problems which were to be correctly worked before a student was assumed to have learned the material and reached criterion performance. In this case, the overlearning was five versus two correctly worked problems for each rule. Retention was measured after seven days, and once again, results indicated no difference between scores for the different practice groups.

A study conducted by Gagné, Mayor, Garstens, and Paradise (1962) also failed to find evidence of the effectiveness of additional practice for learning and retention. In this study, a group of seventh grade students were taught the addition of integers, and one group received four or five times as many practices in each of the subordinate skills as did another group, yet no difference was found in final performance. Similar results were obtained by Gagné (1965), Gagné and Bassler (1963), and Gibson (1969).

As was noted at the beginning of this review, the potential significance of number of practice trials for learning and retention is great, but the amount of research which has been done in this area is quite limited. Research results which are available still leave many questions to be answered. Evidence regarding the value of practice for information learning is contradictory and many who do find increased retention also find a leveling off point after which increased practice has no effect. Relevant research in the area of learning and retention of intellectual skills is even more limited. Results of the studies which have been reviewed indicate no difference in retention scores as related to number of practice trials directly following original learning.

Delayed Practice

More research has been conducted in the area of spaced review than on the variables of number of practice trials, and the results have been much more consistent. In verbal learning, for example, the evidence strongly indicates that delayed review significantly enhances delayed retention.

One such piece of evidence is found in an experiment conducted by Peterson, Ellis, Toohill, and Kloess (1935) to determine the effects of delayed review on the retention of prose. One set of students received a review one week after learning which consisted of a repetition of the conditions of original learning, while another group received no review. Retention was then measured two, three, six, and eighteen weeks after learning by retention tests which were written essay reproductions scored for ideas. Results indicated that, on the whole, the effects of the review were large and relatively permanent.

A number of other studies (Spitzer, 1939, Spencer, 1941; Tiedman, 1943; Ausubel and Youssef, 1965; Reynolds and Glaser, 1964; Gibson, 1965) have also demonstrated the effectiveness of delayed review on retention of meaningful material.

Although relevant research in the domain of intellectual skills is extremely limited, an experiment conducted by Gay (1973) reports findings consistent with those previously noted for meaningful verbal learning. Gay (1973) compared the relative effectiveness of a single review placed one day, one week, or two weeks after original learning. A fourth group received no additional practice following original learning. The students learned four mathematical rules utilizing varying numbers of examples, all learning to a common criterion of two consecutive correct problems. Three weeks from the day of original learning a delayed retention measure on the four mathematical rules was administered to each of the four groups. While all review groups retained considerably more than the no review group, temporal position was not significant as a variable.

In the domains of both verbal information and intellectual skills, findings are consistent with regard to the effect of delayed review in enhancing retention. These findings are consistent over many types of review, including, rereading, test, practice, and relearning to criterion, as well as over different types of retention measures, including multiple choice, recall and construction essay tests. It is also interesting to note that Ausubel (1966) and Gay (1973), while finding increased retention, did not find temporal position of review to be significant.

PURPOSE AND RATIONALE FOR THE STUDY

As previously noted, there is not a great deal of research investigating the relationship between number of practices and delayed retention. One important consideration is either an increased number of practice trials directly following initial learning increases delayed retention. Most of the research which has been conducted on this question has been in the domain of information or verbal learning, and here the evidence is inconclusive. Verbal learning is of unquestionable importance in a student's education, but it should be remembered that a large part of what is learned in the schools comprises intellectual skills, including rules. Available research on this aspect of the problem is limited, although evidence is somewhat more consistent than that for information. Indications are that once a rule or concept has been learned, as demonstrated by reaching a pre-established criterion, any further practice at the time of original learning does not have an appreciable effect on delayed retention.

These findings suggest another question about the relationship of practice to retention of intellectual skills. If practice beyond the criterion performance at time of original learning does not aid retention, what is the effect of practice at some period after original learning?

Research on this question is even more limited, but again, indications are fairly consistent. It appears that this delayed practice, without consideration to number of practices or temporal position, significantly enhances retention.

The present study will further investigate these two aspects of the relationship between practice and performance on a delayed retention measure of rule learning. The following additional implications of these findings will also be explored: number of practice trials has previously been investigated for its effect at a time directly following original learning, but little is known about the possible implications of these findings for number of practice trials at a time after the occasion which includes original learning. Effect of number of practice trials at a delayed time will, therefore, also be investigated. Also, delayed practice, which has previously been compared for effectiveness only with no practice, will, in the present study, be compared with immediate practice as well.

For purposes of this study, a practice trial will consist of working a problem demonstrating a previously learned mathematical rule; immediate practice will be defined as practice immediately following learning to criterion at original learning; and delayed practice will be defined as practice on the fifth day following original learning. It should also be noted here that a criterion problem will be utilized in each case to determine if the student has learned the rules involved. Toward this end, reaching criterion will consist of demonstrating the ability to apply the rule to a novel example by working one problem correctly. It is hoped that this procedure will provide a tool for determining when a student has reached mastery of a rule.

The primary purposes of the study were to contrast the effects of immediate practice (examples given directly following learning) and delayed practice (examples given five days later) on retention of the rules measured after a longer interval (21 days). More specifically, the aims were:

1. To determine whether number of immediate practice trials beyond reaching criterion is effective for retention (21 days).
2. To determine whether retention is affected by number of delayed practice trials.
3. To determine whether delayed practice is effective for retention.
4. To determine the effects of delayed practice, as opposed to immediate practice, on retention.

In addition to the primary purposes of this investigation listed above, a secondary purpose will be to determine the course of retention from the point of initial learning to 21 days later.

METHOD AND PROCEDURE

Experimental Design

The design utilized in this experiment is of the type referred to by Campbell and Stanley (1972) as a posttest only control group design. In this design, Group I (control) received no practice and Groups II through V (experimental) received one immediate, five immediate, one delayed and five delayed practice trials, respectively. It should be noted that practice was defined as problem(s) beyond reaching criterion, which meant working one problem correctly. Consequently, members of each group, including the no practice group, worked one correct problem in reaching criterion which was not counted as a practice trial. The basic design is shown in Table 1.

TABLE 1

PLACEMENT AND NUMBER OF PRACTICE TRIALS AND RETENTION TEST IN THE FIVE GROUPS OF THE EXPERIMENT

Group	Directly Following Learning	Day 5	Day 21
I	0 practice	0 practice	Retention test
II	1 practice trial per skill	0 practice	Retention test
III	5 practice trials per skill	0 practice	Retention test
IV	0 practice	1 practice trial per skill	Retention test
V	0 practice	5 practice trials per skill	Retention test

This design equates for all groups the interval between original learning and retention test rather than that between practice and retention test. Evidence implies that this is not a critical variable, and it is believed that both of these approaches would have yielded much the same results in terms of a comparison of retention test scores. Peterson et al (1935), Gay (1973), and Ausubel (1965) each examined the effectiveness of review, using different ways of counting the interval between learning and retention. Peterson and Gay used time from original learning as the retention interval, whereas Ausubel used time from review. The results obtained in each of these studies were very similar. It is also a consideration that scores for retention after intervals of two weeks or more are unlikely to be affected greatly by differences of a few days in

the designation of the "retention interval." This is true because of the general finding of the leveling off of retention losses beyond two weeks (Gay, 1973).

Materials

In order to investigate the effects of the independent variables, three rules of combining exponents with the same number bases were chosen to be taught to a group of seventh grade students. These rules were (1) multiplying numbers which are written in exponential notation and have the same number base, e.g., $2^2 \times 2^3 = 2^5$, (2) dividing numbers which are written in exponential notation and have the same number base, e.g., $\frac{2^6}{2^2} = 2^4$, and, (3) raising numbers written in exponential notation to a power, e.g., $(2^3)^2 = 2^6$. Selection of these particular rules was made largely on the basis that they were rules not previously encountered by seventh grade students. It was also of importance that entry behavior requirements for these rules involved only the basic skills of adding, subtracting and multiplying, and the skills of writing factors in exponential notation and reducing fractions. These latter skills were easily reviewed or taught by the classroom teacher, prior to the first day of the experiment.

To provide instruction in the three rules, a programmed text, designed to be administered in a classroom situation with teacher assistance, was written. The text was a twenty-four frame, large step program in four sections. Frames 1-5 were a review of writing factors in exponential notation; frames 6-11 were instructions on multiplying numbers which are written in exponential notation; frames 12-17 were instructions on dividing numbers which are written in exponential

notation, and frames 13-24 were instructions for raising numbers written in exponential notation to a power. Each instructional sequence within the programmed instruction was constructed using the following steps for rule learning, as suggested by Gagné (1970):

Step 1: Inform the learner about the form of the performance to be expected when learning is completed.

Step 2: Question the learner in a way that requires the reinstatement of the previously learned concepts that make up the rule.

Step 3: Use statements that will lead the learner to put the rule together, as a chain of concepts, in the proper order.

Step 4: By means of a question, ask the learner to "demonstrate" one or more concrete instances of the rule.

At the end of each section in the programmed text a criterion problem, for which the answer was not given, was included (this corresponds to Step 4 above).

Also developed were sets of one and five practice problems for each of the three skills. For the students in the two groups receiving immediate practice, a separate page containing the appropriate number of practice problems was inserted following the criterion problem in each section. These same practice problems were also administered to the two groups receiving delayed practice.

Subjects

Subjects were the students of one seventh grade mathematics teacher at Griffin Middle School in Tallahassee, Florida. It was determined beforehand that students in mathematics classes at Griffin School are not grouped according to ability. A wide range of ability levels could

therefore be expected to be present among the subjects. These students were particularly well suited to work with a programmed text involving limited teacher assistance, since their normal classroom routine includes a great deal of individual work.

The 134 subjects involved were randomly assigned to the five treatment groups. Eighteen students, who were absent on the day of original learning or on the day of the retention test were eliminated from the sample. An additional 13 students who either failed to reach criterion for any of the three skills, or who did not complete the programmed text in the allotted time, were also eliminated from the sample. This resulted in a total sample size of 103 with the representation of each group as follows: 27, no practice; 20, one immediate practice trial; 18, five immediate practice trials; 18, one delayed practice trial; and 20, five delayed practice trials.

Procedure

Administration of the programmed text was carried out during the students' math period by the regular classroom teacher and a student intern who had been working with her. In order that the time interval between original learning and delayed practice would include a period of non-school activity, the text was administered on Wednesday, when Thursday and Friday were to be school holidays. The two delayed practice groups then received their practice trials the following Monday.

On the day of original learning programmed texts were distributed according to the random assignment of students to the five treatment groups. The classroom teacher then read through directions for working the

instructional material with the students. Students were instructed to proceed with the programmed text by working each frame, writing their answer, and checking it against the correct answer which was given in the lower right hand corner of each frame. If their answer was incorrect, they were to do enough work to see why the answer given was correct, and if they still did not understand, they were to request help from the teacher. In this manner, students were to work each section of the text and raise a hand after completing the criterion problem, for which the answer was not provided, so that their answer could be checked. Either the teacher or the intern then checked the student's answer to the criterion problem. If the answer was correct (indicating that the criterion had been reached for the skill involved) the student was instructed to turn the page and begin the next section. Teacher and intern had previously been provided with an alternate criterion problem for each of the three skills. If a student had answered a criterion problem incorrectly, he was told the correct answer and given the alternate problem to provide him a second opportunity to reach criterion. If this problem was not answered correctly, it was so indicated on the text, and the student was later eliminated from the sample, although he was instructed to turn to the next section and allowed to complete the instructional material. As students completed the programmed text, it was collected immediately and the students were assigned work typical of their normal classroom routine. This was done in order to prevent them from looking back through the text or rehearsing the material after the text had been collected.

The one no practice group and the two delayed practice groups followed the above procedure throughout the administering of the programmed instruction. The two groups receiving immediate practice trials followed the same procedure, with the exception of the inclusion of either one or five practice problems on a separate page immediately following each criterion problem. In these instances, after a student's criterion problem was checked he was instructed to turn to the next page, where he worked the practice problem(s), and raised his hand to have his answer(s) checked. After the practice problem(s) had been checked, the student was given only the correct answer(s) for the problem(s) he had missed and instructed to turn the page and begin work on the next section.

Practice problems were distributed on the following Monday, to the two delayed practice groups. These students received a page containing either one or five practice problems per skill, or a total of either three or fifteen problems. As with the immediate practice groups, subjects in these groups were instructed to raise a hand after completing the practice problems, their answers were checked and the correct answers given. Again, no additional information was provided. During the time delayed practice trials were being administered to these groups, the remainder of the students continued to work on individual classroom projects which the teacher had previously assigned.

Retention Test

Three weeks from the day of original learning the retention test was administered. This test was developed by constructing a nine-item

pool for each of the three skills to be tested and randomly selecting four problems from each. In this way, a twelve-item retention test was constructed, consisting of three sections, one for each skill to be tested, with students receiving a separate score for each skill. Consequently, there were three dependent measures for each student, one for each skill he had learned. The remaining five items of each item pool were used as the practice problems, with the first of each set of five being used for the groups having one practice trial.

RESULTS

Retention Scores

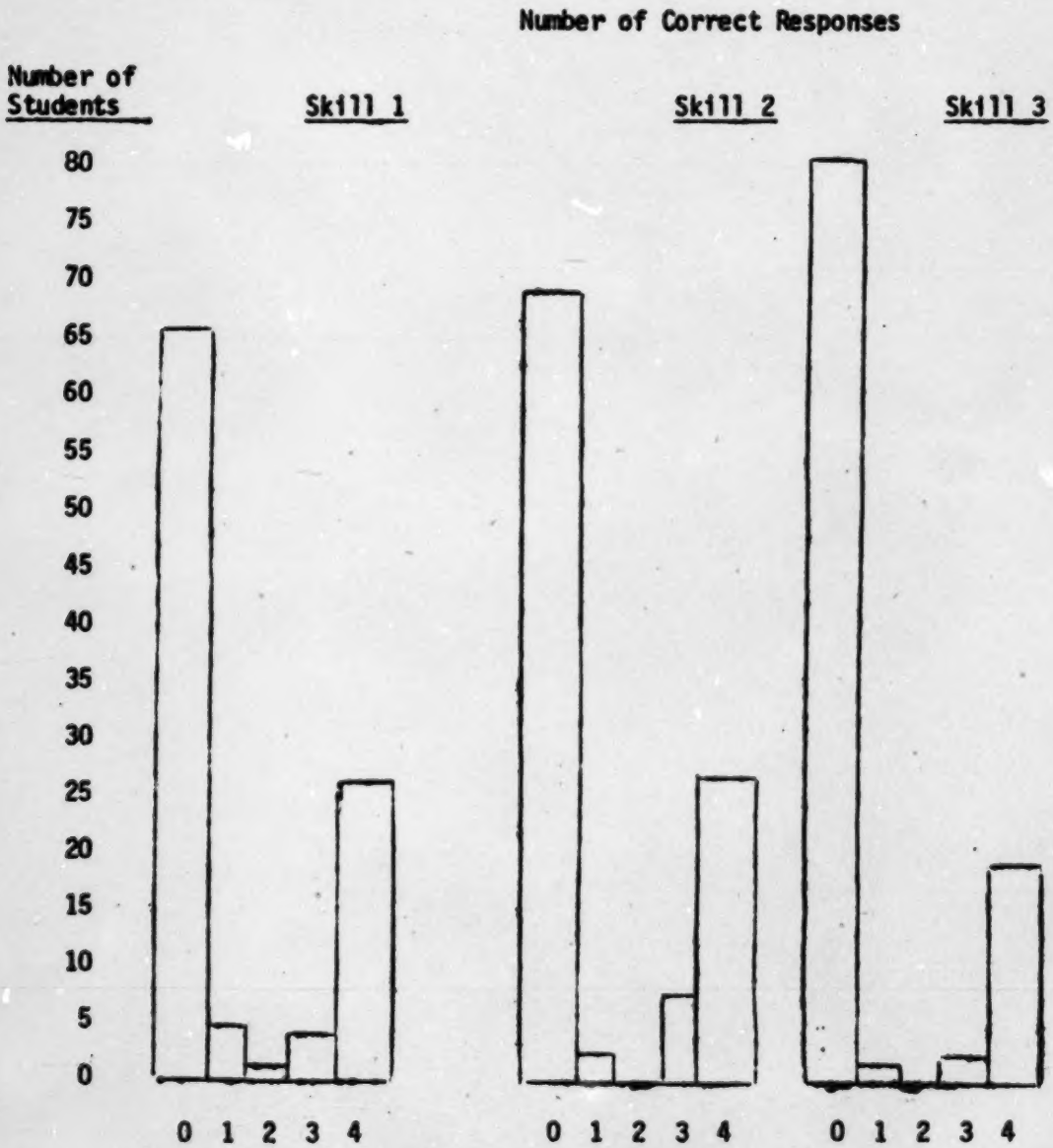
Three weeks following original learning a delayed retention measure was administered. The measure used was a test consisting of twelve problems, four for each of the three skills. Scores for each of the skills were considered individually.

Table 2 gives a breakdown of retention test scores by number of students working 0, 1, 2, 3, or 4 correct problems for each skill.

A review of the scores in Table 2 reveals that only one subject scored two correct problems for a skill. With 103 subjects participating and being tested on three skills, this means that a score of two correct problems was made only one time in 309 opportunities. This finding and the clustering of scores at 0 or 1 and 3 or 4 correct problems would clearly seem to indicate that a student either had mastered and could apply the skill, or had not. For this reason, the scoring procedure selected was that of accepting a score of 0 or 1 to indicate a student

TABLE 2

RETENTION TEST SCORES BY SKILL



could not perform the skill and a score of 3 or 4 to indicate he could perform the skill. Each student then received a score of either 0, 1, 2, or 3 for the number of skills he could correctly apply.

Utilizing this scoring procedure, the means and standard deviations for the total scores of the five treatment groups were calculated and are shown in Table 3.

TABLE 3

MEANS AND STANDARD DEVIATIONS OF THE FIVE TREATMENT GROUPS

Group	Mean	Standard Deviation
I (no practice)	.93	1.00
II (1 immediate practice trial)	.45	.60
III (5 immediate practice trials)	.56	.62
IV (1 delayed practice trial)	1.00	1.00
V (5 delayed practice trials)	1.25	.85

Table 4 gives a breakdown of practice trial scores by number of students in the five immediate and five delayed practice trial groups working 0, 1, 2, 3, 4, or 5 correct problems for each skill.

TABLE 4

PRACTICE TRIAL SCORES BY SKILL

	Number of Correct Responses																	
	Skill 1						Skill 2						Skill 3					
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
Immediate																		
Number of Students	0	0	1	0	1	16	0	0	0	0	2	16	0	0	0	0	1	17
Delayed																		
Number of Students	10	0	0	0	2	8	11	0	0	0	0	9	13	0	0	0	0	7

Tests of Hypotheses

The total number of subjects was 103 and of this number, 45 subjects received scores of 0, 34, scores of 1, 19, scores of 2, and 5, scores of 3. In view of the nature of these scores, it appeared that non-paparetric methods of data analysis would be most appropriate. Since the scores could be viewed as ordinal measures, Wilcoxon rank-test was utilized for pairwise comparison and Kruskal-Wallace was utilized for one-way analysis of variance tests. Each null hypothesis was tested at the $\alpha = .05$ level.

Effects of immediate practice trials. In order to determine whether number of immediate practice trials beyond criterion is effective for retention (21 days) the following null hypothesis was tested:

Ho: Group 1 = Group 2 = Group 3 (There is no difference among the distribution of the scores of the group receiving no additional practice trials,

the group receiving 1 additional immediate practice trial and the group receiving 5 additional immediate practice trials.) The probability of this occurrence under the null hypothesis was found to be greater than .05, therefore, the null hypothesis was not rejected. In other words, immediate practice trials, as few as one or as many as five, are not found to have significant effects on retention scores.

Effect of number of delayed practice trials. In order to determine whether retention is affected by number of delayed practice trials, the following null hypothesis was tested:

Ho: Group 4 = Group 5 (There is no difference between the distribution of the scores of the group receiving 1 delayed practice trial and the group receiving five delayed practice trials.)

The probability obtained under the null hypothesis was greater than .05 and the null hypothesis was not rejected. As a result of this analysis, it would appear that number of practice trials at a delayed time is not significantly effective for delayed retention.

Effect of delayed practice trials. In order to determine whether delayed practice is effective for retention, the following null hypothesis was tested:

Ho: Group 1, 2, and 3 = Group 4 and 5 (There is no difference between the distribution of the scores of the group composed of those receiving no additional practice trials, or 1 or 5 additional immediate practice trials and the group composed of those receiving 1 or 5 additional delayed practice trials.)

This hypothesis (normal approximately = 2.53, $p < .05$) was found to have a probability of occurrence under the null hypothesis of less than .05

and was therefore rejected. This result indicates that delayed practice as compared to no practice and one or five immediate practice trials is effective in enhancing delayed retention.

Effect of delayed vs. immediate practice trials. The fourth null hypothesis to be examined was designed to determine the effect of delayed practice trials as opposed to immediate practice trials on retention. This hypothesis was as follows:

> Ho: Group 4 and 5 = Group 1 and 2 (There is no difference between the distribution of the scores of the group composed of those receiving 1 or 5 additional immediate practice trials and the group composed of those receiving 1 or 5 additional delayed practice trials.

This hypothesis (normal approximation = 3.05, $p < .05$) was found to have a probability of occurrence under the null hypothesis of less than .05 and was therefore rejected. This result indicates that delayed practice trials are more effective than immediate practice trials for delayed retention (21 days).

Curve of Forgetting

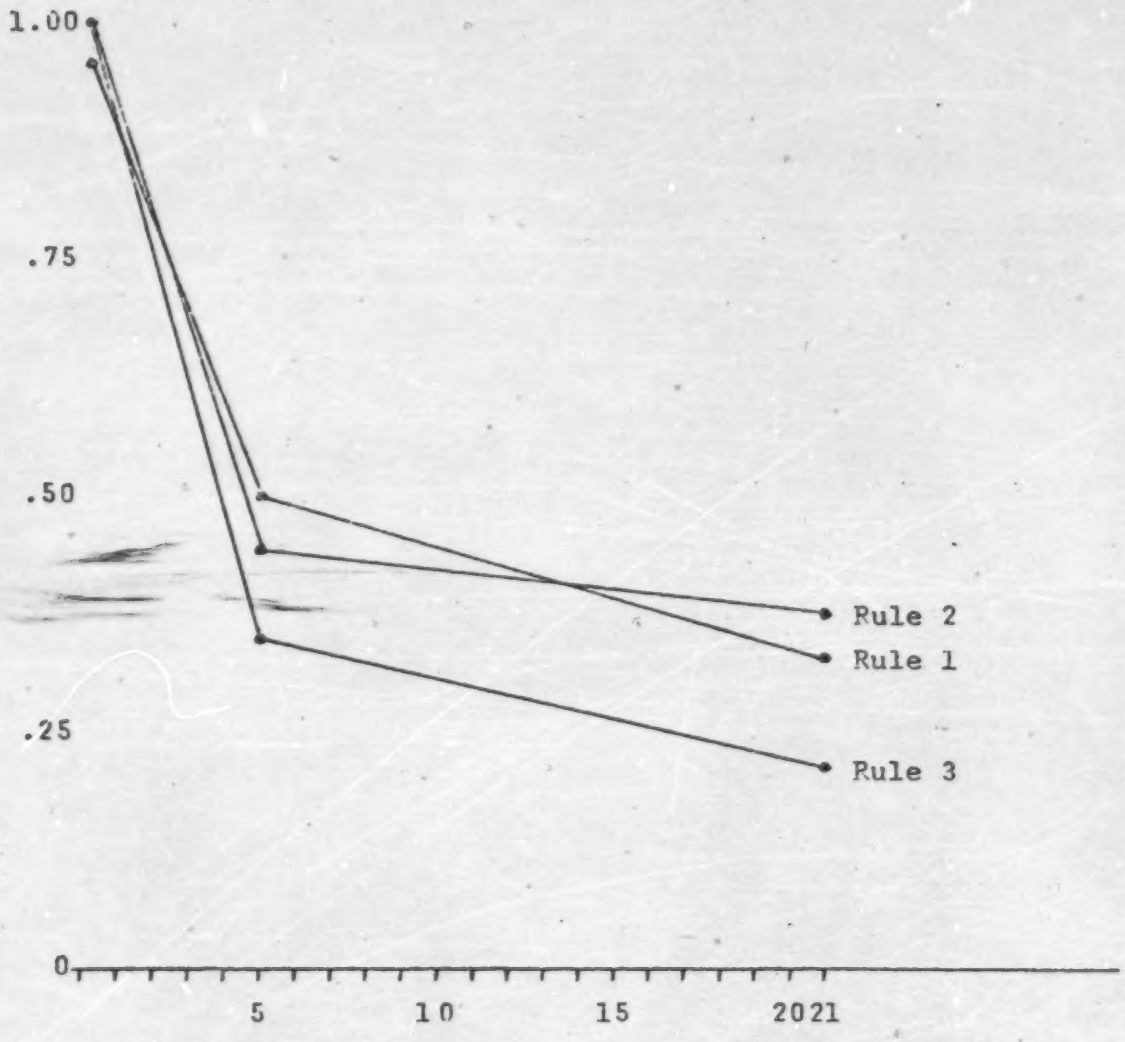
To determine the course of retention from point of original learning to 21 days without the influence of additional practice trials, three retention curves (one for each of the three skills) were plotted. The first measure of retention utilized the practice trial scores of the five immediate practice group. The second measure of retention was made on the fifth day after original learning by using the scores of group five (five delayed practice trials) on the practice trials they received for each skill.

A final measure was obtained by utilizing the scores of group one (no practice) for the delayed retention measure (21 days).

These curves of forgetting may be found in Figure 1.

FIGURE 1

CURVES OF FORGETTING BY SKILL



As can be seen from this figure, retention was virtually 100% immediately following original learning, but dropped to approximately 40% on day five. An additional, but less substantial drop in retention was experienced between day five and day 21, with scores of the delayed retention measure indicating a retention of approximately 30%. In general, total retention loss was quite high, and the greatest losses occurred within the first five days following original learning. Retention loss appears to have leveled off somewhat, however, between delayed practice on day five and delayed retention measure on day 21.

DISCUSSION

The present study was designed to answer several questions regarding the relationships of number of practice trials and immediate and delayed practice trials to the delayed retention of rule learning. Examination of the retention test scores failed to reveal a significant effect on delayed retention for number of immediate practice trials when compared with a group receiving no practice. Scores for the delayed practice groups, 1 receiving 1 and 1 receiving 5 practice trials, were also examined in an effort to determine the effectiveness of number of delayed practice trials for delayed retention. Again, no significant difference was revealed.

A significant difference in effectiveness of delayed practice trials for delayed retention was revealed when scores of the group composed of the one and five delayed practice groups were compared with scores of the group composed of the no practice and 1 and 5 immediate practice groups. A comparison of the effectiveness of immediate and

delayed practice trials also revealed a significant difference in delayed retention scores in favor of delayed practice.

The finding of no significant effect on delayed retention for number of immediate practice trials is in agreement with findings of earlier studies investigating number of practice trials and intellectual skills (Bassler et al, 1971. Hannum, 1973. Gagné et al, 1962, Gagné, 1965; Gagné & Bassler, 1965. Gibson, 1969). Since an important aspect of this investigation was that all subjects learned the material to the same preestablished criterion of working one correct criterion problem for each skill, these findings provide additional support for the position that additional practice trials beyond mastery appear to have no significant effect on delayed retention of intellectual skills (Gagné, 1970).

While there appears to be no previous literature examining the effectiveness of number of practice trials at a time after original learning, the finding of no significant difference in the effectiveness of one and five delayed practice trials was not unexpected. Existing research on effectiveness of number of practice trials for delayed retention of intellectual skills has been conducted with practice trials at time of original learning and most has found no significant differences. From these findings one might expect, as was the case in this study, that number of practice trials at a delayed time would also not prove significant in its effect on delayed retention.

The significant difference in scores between the group composed of 1 and 5 immediate practice groups and the no practice group and the group composed of the 1 and 5 delayed practice groups, as well as that between a comparison of just immediate and delayed practice groups, is

consistent with implications of earlier research on intellectual skills. While no research appears to have been performed to investigate these specific relationships, studies of two related questions would suggest these findings. Number of practice trials beyond mastery (immediate practice) has not been shown to be effective for delayed retention and delayed practice has been shown to be effective in improving delayed retention when compared with no practice.

Implications

Various research studies cited in earlier sections of this paper found high rates of forgetting by students of material learned in the classroom. This research dealt with various types of learning outcomes, both verbal and intellectual. The results of the present study, which investigated retention of three clearly defined mathematical rules are no different in this respect than those of earlier investigations. From a demonstrated retention of nearly 100% immediately following original learning, subjects in this study showed a retention of only 40% after just five days and 30% after 21 days. Forgetting of these skills was substantial.

Retention measure scores for each student suggest some additional information concerning the learning and forgetting of intellectual skills. Clustering of retention measure scores for each skill at either high or low scores with very few of inbetween value has previously been mentioned. When a clearly defined skill is taught and its mastery and retention are measured in a way which unambiguously represents that skill, these results imply that the skill is either accessible or non-accessible. The outcome

of instruction designed to teach a specific skill and the attainment of that skill may best be considered not in terms of any degree of learning, but as learned or not learned, i.e., mastered or not mastered.

Another implication suggested by the findings of this study is that learning to a set criterion of performance could be a very important key to the learning and retention of intellectual skills. This study in examining immediate practice has found no significant effect on delayed retention of mathematical skills for practice trials beyond mastery. Hannum (1973) obtained similar results in an investigation of the retention of rules in electricity. Gay (1973) found that increased retention resulted from having subjects relearn to criterion at a time after original learning. Perhaps the factor which should be given more consideration then is not number of practice trials, even at a delayed time, but rather the requirement that a student learn to a mastery criterion.

Results of this study do not show improved retention of intellectual skills to result from additional practice. This result contrasts with that obtained for other areas of learning, particularly verbal learning. The present findings are of importance for the learning and retention of intellectual skills. They suggest a new role for number of practice trials and delayed practice as aids to delayed retention. Additional practice trials may have their effects in terms of amount of practice necessary to reach mastery, rather than as number of practice trials beyond criterion ("overlearning"). Delayed practice is presumably more effective than immediate practice because it serves as a source of cues to retrieval of the desired skill. If the intent is to improve retention, the suggestion is to search for other ways of cueing retention and retrieval. Practice which includes relearning to criterion may offer one possibility.

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